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NOTES ON ECONOMIC ENTOMOLOGY—No. I.

A

PRELIMINARY ACCOUNT

OF THE

WHEAT AND RICE WEEVIL IN INDIA.

BY

E. C. COTES,

FIRST ASSISTANT TO THE SUPERINTENDENT, INDIAN MUSEUM.

CALCUTTA

PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA.

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PREFACE.

IN the following account of the wheat and rice weevil of India, an attempt has been made to gather together what is already known about the insect, and to supplement it from information obtained from practical men in India.

The chief points which are uncertain or unknown in its history have been indicated, in the hope that some of those who take an interest in the matter may assist in obtaining the information which is wanted: as it is only from a most minute and accurate knowledge of its habits and peculiarities that reliable inferences can be drawn.

Appended to the general account are abstracts and translations of the chief writings of entomologists, both on this particular species and also on its near ally, the wheat weevil of Europe, whose history throws considerable light on points connected with Indian species; also a valuable series of reports obtained by Messrs. Ralli Brothers from their agencies in different parts of India.

The writer's best thanks are due to Messrs. Ralli Brothers, Mr. J. Blackwood, Junior, Dr. G. M. Giles, and to Mr. W. Wishart, in India; to Professor Westwood, in England; and to Mr. L. O. Howard in America, for assistance rendered.

E. C. COTES,
Indian Museum.

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PLATE.

Calandra oryzæ, Linn.

Fig. 1.—Imago, dorsal view ; drawn from the specimen.

„ 2.—Imago, lateral view ; drawn from the specimen.

„ 3.—Pupa ; enlarged from Miss Ormerod's figure in "The Entomologist," XII, 1879, p. *53*.

„ 4.—Larva ; enlarged from Miss Ormerod's figure in "The Entomologist," XII, 1879, p. *53*.

„ 5.—Imago, and grain of infested wheat, natural size ; drawn from the specimens. (The weevil is rather smaller than it is depicted.)

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THE INDIAN WHEAT AND RICE WEEVIL.

CALANDRA (SITOPHILUS) ORYZÆ, Linn.

In the latter part of June grains may be seen in the heaps of wheat that has been harvested in the early part of the hot weather, each with a hole drilled into it, and a considerable part of the contents eaten away; this is the work of the wheat weevil *Calandra* (*Sitophilus*) *oryzæ* of Linnæus. The perfect beetles may at the same time be found creeping about the upper layers of the grain and coming to the surface in large numbers when the heap is disturbed. From the end of June onwards, when no measures are taken to check the pest, the amount of damage steadily increases, as much as 5 per cent. of the wheat being sometimes destroyed.

Nature of the damage.

The soft varieties of wheat are the most attacked; Delhi, Buxa, and Hanskhali[1] wheat being the worst, while hard red wheat is but slightly damaged.

The amount of loss occasioned by weevil is estimated[1] by Messrs. Ralli Brothers at an average of 2½ per cent., the maximum being 5 per cent. and the minimum one per cent. Taking the value of wheat exported at six million[2] pounds sterling, the annual loss occasioned by weevil in exported wheat alone is £150,000. This sum, however, in reality represents but a fraction of the real loss, as it does not take into account the damage done to wheat consumed in the country, or any of the loss occasioned to rice, which is also attacked by the same weevil, besides the loss indirectly occasioned owing to the difficulty of storing the grain.

Estimate of amount of loss.

Besides the actual pecuniary loss occasioned by weevil there is some evidence to show that the flour made from weevily wheat, in which a certain number of the insects are ground up, is likely to be injurious to health; as the beetles contain certain vesicant properties,[3] which are known to be powerful irritants to the urinary organs even in extremely minute doses.[4]

Unwholesomeness of weevily grain.

[1] Messrs. Ralli Brothers' answers to queries.

[2] Statistical Atlas of India, page 36, estimate for 1885.

[3] *Vide* American Entomologist I, page 179; and Transactions of the Entomological Society of London, Vol. I, page 241 (1836).

[4] Note by Dr. G. M. Giles.

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Stored grain in different parts of the world is liable to be attacked by two distinct species of weevil, *viz.*, *Calandra* (*Sitophilus*) *granaria* and *Calandra* (*Sitophilus*) *oryzæ*. These two species are so much like each other and have habits so nearly identical, that no study of the subject would be complete without taking both species into consideration. *Calandra granaria* is supposed to have been introduced into Europe from the East (probably from Egypt), and now occurs throughout the whole of Europe and America. It is a little larger than *Calandra oryzæ*, but superficially almost xactly like it; it is, however, without the light coloured spots on the elytra, and has the clear medial smooth space on the dorsal surface of the prothorax somewhat more defined. It is said to be entirely confined to granaries, attacking wheat, rye, and maize, and requires a considerable amount of warmth for its development. In the appendix to this paper full description of it will be found, which are valuable from the light they throw some points in the history of the Indian wheat weevil *C. oryzæ*, and from the fact that several of the methods that are suggested for combating it are equally applicable to both species.

The occurrence of two species.

The Indian Species.

The weevil found in Calcutta in wheat and rice is *Calandra* (*Sitophilus*) *oryzæ* of Linn.

In spring the female punctures grains lying in granaries with her jaws, and deposits one egg in each grain. "The puncture is somewhat curved, rather less than $\frac{1}{16}$ of an inch (1·5 m.m.) deep, and rather narrower at the bottom than at the opening. The egg, which is 0·5 m.m. long, elongate, ovoid and translucent, is pushed to the bottom, and the whole space above it is then filled in with particles of grain gnawed into fine powder like flour. The orifice being pasted with a little saliva,"[1] is so well concealed as to be imperceptible except on the very closest examination.

The egg.

The larva (fig. 4) rapidly hatches and bores its way into the heart of the grain. It is a thick, fleshy grub, and when full-grown is from 1·5 m.m. to 8 m.m. in length, when at full stretch, but somewhat less in the usual curved position, and its breadth is about two-thirds of its length. The grubs are obtuse, legless, and white; the head chestnut colour; jaws also chestnut, darker at the extremity, bluntly pointed, and waved into blunt teeth. The segment behind the head, and the candal extremity, with a few small bristles. The figure represents a specimen fairly well with the numerous corrugations which confuse the primary segments with the lesser folds, the underside being a complete mass of almost scale-like corrugations.[2]

The Larva.

[1] Prof. C. V. Riley's article, *Farmers' Review*, Chicago—*see* appendix.

[2] The description and figure of the arva are taken from Miss Ormerod's paper in *The Entomologist*, Vol. XII, 1879.

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Indian Wheat and Rice Weevil by E. C. COTES.

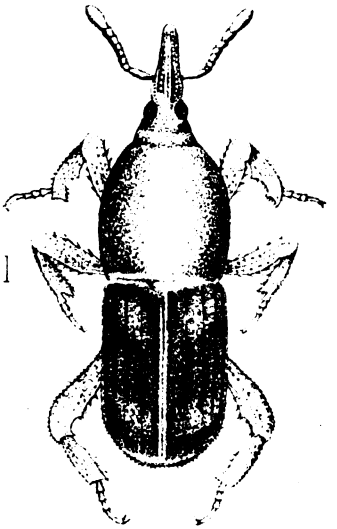

Fig 1.

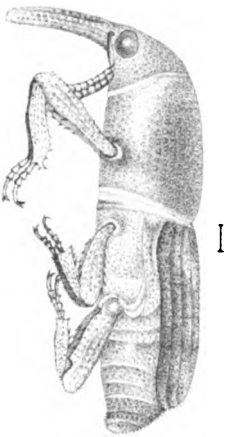

Fig. 2.

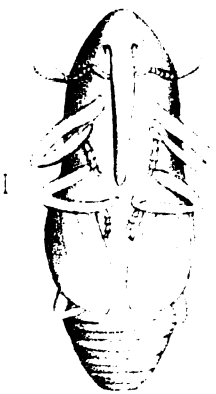

Fig 3.

Fig. 4.

Fig. 5.

Calandra Oryzæ Linn. Natural Size.

Girish Ch Chuckrabotty, del.

Lithographed at the Survey of India Offices, Calcutta, March 1888.

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Pupa. The larva transforms into a pupa (fig. 3) within the grain without making any perceptible opening

The Beetle. The perfect insect (figs. 1 and 2) is a small dark brown beetle about 3·5 m.m. (⅛ inch) long and a little more than 1 m.m. broad. The head is produced into a rostrum, slightly curved, and marked with coarse longitudinal furrows, composed of somewhat irregularly disposed pits. The antennæ are elbowed between the long basal joint and the six-jointed stock, and terminate in an oval club. The eyes are lateral and black. The top of the head is finely punctured and the prothorax more coarsely so, the punctures decreasing in size towards the middle line which is comparatively smooth. The elytra are striated with coarse punctures, and each has one rust red coloured spot on the shoulder and another behind the middle, which are very variable in size and shape. The terminal portion of the abdomen is free, and the wings are weak and apparently ill-fitted for flight. The underside of the insect is uniform in colour with the upperside; the whole of the body and legs being covered with punctures throughout, and sprinkled with short, yellow stubbly hairs that are not visible in all lights.

The first considerable opening in the integument of the grain is made when the imago (or perfect beetle) quits the pupa case and cuts its way out of the grain, leaving a hole about one millimeter in diameter leading into the considerable chamber, previously occupied first by the larva and afterwards by the pupa, and into which the beetle frequently creeps for shelter. Until the actual emergence of the beetle, infested grain, though it is somewhat lighter in weight, is superficially almost exactly like sound grain, as the hole made by the female, in depositing her eggs, is almost imperceptible; and to this, the fact that wheat is supposed to be practically free from weevils until the end of June, may probably be attributed. What is suspected by the writer being that about the end of June is the time that the first generation of beetles emerges from the grain. The time taken for the egg to develop into the perfect insect would appear to be from about six weeks to two months. The rate of development, however, probably depends to a great extent on temperature, as some weevils reared in England required 13 months[1] for the completion of a single generation.

Some beetles kept in the Indian museum were found coupling in January, but there is probably no very definite time for this operation to take place, as they have been observed in England coupling in September.[1]

The wheat and rice godowns in Calcutta, visited in January of this year (1888), were simply swarming with the beetles, which were to be

[1] Entomologist, XII, 1879.

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found in vast numbers in last year's grain, and also on the walls and floor of the sheds. Maize and barley are also said to be attacked (see appendix).

Entomologists seem to be fairly agreed that *C. oryzæ* is only found in stored grain, though some observations point to its occurring elsewhere (see appendix).

Conclusive proof that rice, originally free from weevil, can be infected in the granary, was found in some godowns in Calcutta (January 1888), where was a considerable amount of yellow rice, which had been harvested in the latter part of 1886, and shortly afterwards dipped in boiling water to facilitate the removal of the husk. This rice was simply swarming with weevils—which could not possibly have survived, in any stage of their existence, the immersion in boiling water, and hence must have got into the rice when it was lying in the granary.

A series of wooden (kutcha) godowns and brick-built (pucca) ones were found in the same place in close juxtaposition; the walls, floors, and the crannies and corners simply swarming with beetles; weevily rice, harvested in 1886, lying close to rice harvested in 1887, which had been very recently husked, and in which, after careful search, weevils could not be found. Here was a brick-built godown which had been thoroughly repaired in the preceding year, plastered, cleaned, a new floor put in, and the wood-work thoroughly mended, the rice in this godown had been passed through boiling water, so must have been uninfested when put into the godown; and yet it was found full of weevils. The door of this godown, however, opened directly on to other old infested godowns, and was said to have been frequently opened to remove small quantities of the rice, which would abundantly account for the presence of the pest, for a very few fertile females introduced in the first instance, each capable of laying a hundred or two of eggs, would increase in geometrical progression, and so suffice, in a few months, to infest a very large quantity of grain.

What was found in these godowns is probably typical of other granaries; and quite accounts for what seemed puzzling at first, *viz.*, that grain stored in well-built brick godowns is said to be as much affected as that stored in wooden godowns.

Hymenopterous parasites.

Like almost all other insects, the wheat weevil is not exempt from the attack of Hymenopterous parasites. Fitch (Entomologist, volume XII, 1879) writes, that he has met with two (probably three) species of chalcididæ, and that Curtis knew another. Comstock also[1] describes a small steel blue chalcid parasite with large red eyes, *Pteromalus calandræ* Howard, which resembles, though it is probably distinct from the species

[1] United States Department of Agriculture Report, 1880, p. 273.

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found in January 1888, creeping on a sample of weevily wheat in Calcutta. It seems however that, unlike many other insect pests, the numbers of the weevil are not affected to any considerable extent by the attack either of parasites or of other insect enemies, it is therefore on artificial remedies that reliance must chiefly be placed.

Remedies.

Wheat stored, so as to be practically airtight, is said to be free from the attack of weevils. The method, which seems to have been widely adopted in India, is as follows: holes are dug in the ground, or round buildings of mud are erected, the floor and walls in each case being lined with chaff or sand, and the grain covered with a layer of the same material, the whole being covered in with closely packed earth. Wheat so stored for three years has been found, on opening, to be quite sound.[1]

Spreading wheat in the sun and stirring it occasionally, is said to make the weevils leave it; care must be taken to spread the wheat not more than a quarter of an inch thick, otherwise the weevils in endeavouring to avoid the sun will succeed in finding shelter beneath the grain.[2]

Spreading the grain out, so as to expose the weevils to the cold night air in winter, is also said to destroy the weevils.[1] It would seem, however, to be doubtful to what extent the eggs, larvæ, and pupæ of the weevil would be destroyed by exposure to either sun or cold; and if they are not destroyed, these measures must be obviously of very transitory benefit.

Weevils seem to be very sensitive to odours,[3] and it has been stated (see appendix) that hops, Fennel seed, Larkspur, Elder flowers, Rue, Lavender, Coriander, and other vegetable substances, when mixed with infested grain, cause *C. granaria* to quit the heap. The writer has been told, by Natives in the Calcutta rice bazar, that rice mixed with garlic is free from the attack of the Indian species. The leaves of the Neem tree have also been recommended for this purpose;[4] and the writer would suggest the flowers of *Pyrethrum cinerariæfolium*, which have been largely used in America as an insecticide, for experiment in this connection.

Professor Church, in a memorandum issued by the Revenue and Agricultural Department, recommends the use of bisulphide of carbon: this would appear to be deserving of careful experiment, bisulphide of carbon having been utilized in a somewhat similar way against the grain moth *Gelechia cerealella* in America.

[1] Report of Messrs. Ralli Brothers, Agents in Jubbulpore.
[2] Report of Messrs. Ralli Brothers, Agents in Buxar.
[3] Ernest Menault "Insects nuisibles a l'agriculture.
[4] Journ., Agri.-Hort. Soc., Ind., vol. V, appendix, p. 147.

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He writes:—

"The only cheap and perfect application for the prevention of the attack of weevil upon corn and grain consists in the employment of bisulphide of carbon. The quantity required, provided the grain is kept in closed vessels, is very minute, not more than 1½lbs. to each ton of grain, so that 8*d*. is the cost of preserving a ton of wheat.[1] The bisulphide leaves no disagreeable taste or smell behind, but the quality of the grain remains unimpaired. When bags are used instead of the iron cylinders, specially prepared for use in the bisulphide process, the protective influence of this chemical soon ceases, and a fresh application of the bisulphide must be made. In either case this liquid is applied as follows: a ball of tow is tied to a stick of such a length that it can be just plunged into the middle of the vessel containing the grain. The tow receives the charge of bisulphide like a sponge, and is then *at once* plunged into the sack or cylinder and left there, the mouth being tightly closed. When necessary the stick may be withdrawn and the charge (of 1 oz. of bisulphide to 100 lbs. of corn) may be renewed."

Mr. L. O. Howard, of the United States Department of Agriculture, Division of Entomology, writes in a letter which will be found in full in the appendix:—

"It is, however, considered a very good idea here in America to establish a large 'quarantine' bin into which all grain is put after receipt and disinfected by means of a little bisulphide of carbon. It is then removed and stowed away. The bin in question must be made as tight as is possible, and the method of using the bisulphide is to place a pound or so in a shallow vessel on top of the grain. The vapour of this rapidly volatilizing substance is heavier than air and sinks through the mass destroying all contained insects. Care should be taken in its use on account of its extreme inflammability. The airing which the grain will get in removing it from the bin will probably be sufficient to rid it of the odour."

Mr. F. W. Cabaniss recommends the use of naphthaline powder, which he says will drive out some of the weevils and kill the rest, without injuring the grain for germinating or for the market, as the odour leaves it in a short time, the powder evaporating completely and hence not affecting the grain for food purposes. Further investigations on the subject would, however, appear to be desirable.

Mr. Cabaniss writes:—

"It is best to place the naphthaline powder at the bottom of the bin or bulk of grain. To accomplish this, take a bamboo about 1½ inches in diameter and long enough to reach from the top to the bottom of the bulk of grain. Punch the joints out of the bamboo so as to be able to pass a stick through from one end of the bamboo to the other. Have the stick made to fit the cavity in the bamboo. Pass the bamboo with the stick in it down through the bulk of grain from the top to the bottom. Withdraw the stick and drop into the top of the bamboo about half a teaspoonful of naphthaline powder. The bamboo can then be drawn out as the naphthaline is safe at the bottom of the bulk of grain. If the bulk is large this should be done one to every 10 feet square of the bulk. Repeat the application every 15 or 20 days as the powder evaporates."

Of all the remedies which have been suggested, the most effective is, no doubt, to grind up the grain, or to heat it in an oven, to kill the insects, but this will probably, in the majority of cases, be impracticable;

[1] Bisulphide of carbon can now be bought at about twelve annas per pound in Calcutta.

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and even after the grain has been baked, unless the granary be thoroughly cleared out and disinfected, there is every probability that it will be again attacked.

Vast numbers of the pest may probably be destroyed by sifting, the meshes of the sieve being large enough to allow the weevils to pass, while at the same time retaining the grain; only such weevils, however, as are running about, will be got rid of by this operation, the ones that have taken refuge in excavated grains and all the eggs, larvæ, and pupæ escaping.

Refracting is no doubt useful, but here also many grains, containing larvæ and eggs, which are not yet sufficiently light to be refracted out, will remain to propagate the evil.

The ventilation of grain has been successfully used in Europe for *C. granaria*, as the insect is unable to develope when the temperature falls below a certain point. This method, however, effective as it has been found in a cold climate, does not seem promising in India. In fact, Messrs. Ralli Brothers write that wheat stored in sacks, where it is more exposed to the air than wheat stored in bulk, is also more affected by the weevil.

Rags, or sheep skins spread, wool downwards, at the foot of the heaps of grain, which is then turned over, have been found useful in the case of *C. granaria*, as the beetles creep out in vast numbers when the grain is disturbed and take refuge in the nearest shelter, so that by immersing the rags and wool in boiling water great numbers are destroyed.

[1]Miss Ormerod suggests "the plan of trapping by setting vessels of water," which, she says, attract the beetles in great numbers from the grain.

Prevention.

The question of prevention is an important one, but the extent to which it is possible is a good deal mixed up with the question of whether the Indian weevil, like the European one, is confined to granaries, or occurs also in the fields. In the first case fresh grain, brought in from the fields, and stored in disinfected granaries, would necessarily be free from weevil; while in the second case, it would be necessary to clear the fields of the insect as well as the granaries, an operation which would obviously be very much more difficult. Entomologists, with some exceptions, seem to incline to the belief that the weevil is confined to granaries; there is, however, some evidence on the other side, and it is of great importance that this question should be settled definitively. It has been seen (p. 4) that grain can, and probably in the majority of cases is, affected, in the first instance, when lying in the granary, and it seems to be the general opinion, as gathered from Natives questioned on the subject in Calcutta, and from the

[1] Entomologist, Vol. XII (1879).

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majority of the answers received from Europeans, that the weevil is never found on unharvested grain.

In this connection it should be remembered that the cold, which is probably a quite sufficient reason in itself for the fact that the European species is only found in granaries, does not exist in India.

Messrs. Blechynden and Stewart have brought to the writer's notice cases where wheat has been threshed out on mud floors in the open fields, and stored without delay in new buildings constructed for the purpose; the grain, nevertheless, becoming infested with weevils. This would point to grain in some cases being infested while in the fields. It is only fair to add, however, that in these cases the grain was not stored with a view to ascertaining whether grain so treated would be free from weevil, and consequently allowance must be made for the possibility of infested grain having lain in the neighbourhood unobserved, infested granaries being admittedly in each case to be found within a few hundred yards of the spot.

On the whole, then, it would seem probable that the weevil is generally confined to stored grain, and hence that, by bringing in grain straight from the fields and storing it in disinfected granaries, the pest will be avoided, while it would seem not improbable that in some cases the insect may find shelter in the neighbourhood of the threshing floors, and hence, occasionally, lay its eggs in the wheat before it is removed to the store-house.

The writer would therefore suggest that the following precautions should be taken: clearing up the threshing floors, and the ground near to them, and locating the threshing floors, where possible, well away from infested granaries, taking care that grain is not stored in infested granaries, infested boats, or near to infested grain, and that it is put direct into uninfested buildings, well removed from all infested places. The beetle is apparently ill-fitted for flight. Fitch[1] estimates the rate at which, under favourable circumstances, it can crawl as only about 1 foot per minute,[2] so that the granary need only be separated by a comparatively short distance (a mile would probably be sufficient) from places where affected grain is to be found. It is no doubt the case that in the present widespread condition of the pest preventive measures would have at first to be carried out with the utmost care, but it seems probable that the task is by no means an impossible one. The weevils chiefly inhabit the heaps of grain, but, when these are disturbed, they come to the surface in vast numbers and creep in all directions on the walls and floors, seeking for shelter, and consequently it is morally certain that new grain brought into a store house, from which all last year's grain has not been most carefully

[1] Entomologist, vol XII (1879).
[2] This estimate of pace is probably a little low.

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removed, and the place itself thoroughly disinfected, must necessarily be attacked, and in its turn serve to propagate the pest and carry on infection to other grain.

The greatest care should be taken to prevent the grain becoming affected before it reaches the granary. It must be borne in mind that grain, apparently free from weevil, may, in reality, be badly infested by both eggs and larvæ, as the only sign of the presence of these may be a minute puncture, invisible except on the closest scrutiny.

Before new grain is brought in, the granary should be cleared out, all old grain being most carefully and scrupulously removed, and the whole place thoroughly cleared out, the walls and ceilings white-washed, all cracks in the floor and corners filled up with fresh mortar, and the whole building thoroughly disinfected with sulphur fumes. This is necessary, because the beetle has a habit of hiding itself in chinks and cracks, and so will escape if this cleaning and disinfecting be not of the most thorough description.

The granary should be isolated from other buildings, and care should be taken to remove any rubbish that might afford shelter to the insects; coal tar, which is peculiarly distasteful to insect life, being copiously used on outside work.

If these measures are carried out completely, there seems to be considerable probability that grain will be secured from the attack of the pest.

The disinfection of granaries would no doubt be rendered more complete by washing down the walls, ceilings, and floors with kerosine, to which all insects are particularly sensitive, or with even a diluted emulsion made by violently churning about two parts of kerosine with one part of water in which half a pound of soap has been dissolved, so as to make it possible to efficiently dilute the kerosine with water. It would be necessary to ascertain, however, to what extent the odour of kerosine is prejudicial to the grain.

The insects might, no doubt also to a certain extent, be poisoned by means of common white arsenic, or by the arsenic compounds known as London purple and Paris green. Any application of these poisons, however, would seem to be far too dangerous to be attempted under any circumstances in a granary.

Samples. It may here be added that samples of grain, kept in well closed bottles which contain even a minute quantity of bisulphide of carbon, naphthaline, or camphor, will probably be found to remain indefinitely free from weevils.

Postscript. While the above was passing through the press, the writer had an opportunity of visiting some threshing floors and fields of ripe wheat in Cawnpore, and wheat bazaars

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in Delhi and Rajpore. He was unable to find weevil anywhere in the open, either on threshing floors or in standing wheat, and was informed that ears of wheat, which are hung up exposed to the air, remain indefinitely free from weevil, though the weevils invariably make their appearance, when the grain is threshed out and stored otherwise than in village pits. This is somewhat similar to what has been told him by Mr. R. Blechynden, Jr., *viz.*, that the regular plan adopted by some natives for preserving maize from weevil is to hang the cobs at the end of bamboos and expose them to the air.

In the bazaars were found a considerable number of different lots of wheat which were quite free from weevil, and it appeared on inquiry, that in each case these had recently been brought in from village pits where the wheat had lain, in some cases, for years. The inquiries tended to show that the town godowns have more to do with the infection of wheat than village granaries. In all the godowns visited weevils were invariably found crawling about on the walls. But the graindealers refused to believe that the weevils used the grains of wheat as the depository of their eggs, and insisted that weevils come from outside in June and July and eat up the wheat. They appear to have no idea whatever of the natural history of the insect, and consequently deem it to be of no importance to clean or protect their godowns. Evidently, however, this is one of the most important things to do, as it would decrease, and perhaps avert, the attack of the parent weevil at the time when it is most dangerous, since, as has been already pointed out, the impregnation by a few insects in May will result in a large generation in July.

It is contemplated to issue, with the consent and co-operation of the Agricultural Departments, a simple pamphlet, in the requisite vernaculars, for circulation in some of the leading bazaars, explaining the natural history of the weevil.

There are two possible theories as to the way the weevil originates in the wheat while it is lying in the hands of the middlemen. One is that when the wheat is freshly threshed out, and also when it is taken out of the village pits, it is really free from weevil, and will never develop weevil unless weevils have an opportunity given them of getting at it and laying their eggs in it. This would appear to be the most probable hypothesis, and if it is the true one, there should be no considerable difficulty in preventing the occurrence of weevil altogether by disinfecting the godowns, carts, boats, railway trucks, and ships as has already been suggested.

The second theory, which however would seem to be an improbable one, is that grain, taken straight from the fields, though apparently free from weevil, sometimes in reality contains the almost invisible eggs of the insect which have been laid when the grain was standing

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in the field and only require suitable conditions to develop; and that wheat taken out of village pits in the same way, though apparently free from weevil, in reality may contain the germs of the insect which, though unable to develop in the pit, survive their residence in it and develop as soon as they find themselves under favourable conditions. If this second theory is the true one, it is evident that it is not much use preventing the entrance of fresh weevils; and that disinfection, to be of any service, must be extended to the fields.

The writer hopes this year to have a series of different kinds of wheat, from various localities, taken straight out of the fields, and also from village pits, and sent down to him in Calcutta with sufficient precautions to prevent its getting infected on the road. If, as appears most probable, no weevil is developed in this wheat by the beginning of next cold weather, the practicability of preventing the occurrence of weevils would seem to be to a great extent demonstrated.

It is suggested that similar experiments should be carried out by others who take an interest in the question, and also that observations should be accumulated on the points which have not yet been sufficiently cleared up, in the history of the insect.

For example:

As to the occurrence of the weevil in the open.

As to the length of life of the beetle when deprived of grain on which to lay its eggs, and its bearing in connection with the question of how long after the removal of the infested grain, the place which has contained it must be looked upon as infected.

As to the time normally passed by the insect in its different stages of egg, larva, pupa, and imago, the number of generations in the year, and the dates of their occurrence in various climates.

As to the extent to which the insect is dependent on moisture in its different stages: and the effect of the dry heat of the north-west upon it.

As to the occurrence of the weevil in grain other than wheat and rice.

The writer will always be glad to receive communications bearing on any of the points dealt with in the foregoing account, and especially such as relate to the success or failure of attempts actually made to combat the pest.

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APPENDIX

COMPRISING

EXTRACTS, NOTICES, AND TRANSLATIONS OF WHAT HAS BEEN WRITTEN ON THE SUBJECT, WITH REPLIES TO QUERIES.

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APPENDIX.

'English grain being affected is due always to carelessness or heedlessness in shooting it in old dirty, uncared-for granaries or mills, which themselves are sure to harbour the little beetles, or by laying it in close proximity to some affected foreign corn. With foreign wheat, weevils are a necessity, as it is either affected on shipment or speedily becomes so from the dirty, unswept, and uncleaned granaries into which the corn finds its way. The little pests would certainly be got rid of by shippers to a great extent if they would only try. The improved service and quickened passages have lessened weevil loss in corn to a remarkable extent within the last few years.'

'The wheats which are now affected to any very serious extent are the Indian, and I have often seen samples of the excessively dry Calcutta and South-Eastern Asian wheat in which it was almost impossible to find a perfect corn, the valuable starch of the kernel being consumed by the destructive little weevils.'

'Weevily wheat is invariably dressed after landing, and a large percentage of the little beetles are thus screened or blown out, but of course many of the perfect insects resident in the corn, and all in the larva or pupa state, escape, the kernel not yet being light enough to be separated. When the cargo is very badly affected, when the whole bulk seems alive, as I have myself seen it on very hot summer days, it is a common practice for merchants to spout it, *i.e.*, to shoot the grain down a spouted trough in which, at the angle, is a wire sieve with meshes large enough to let the weevils pass through, but not the corn, which runs into the granary, or into sacks as the case may be. By such means the quantity of weevils and dust sifted out is enormous, and this appliance is generally so situated at the wharves that the beetles are deposited near the edge of the wharf or even in the river bed, and if not naturally washed away at high tide, are swept into the water, their destruction being thus easily accomplished. The great heat generated in a bulk of weevily corn is caused by the dust arising from the borings and frass of the insects. The weevils themselves are generally to be found inside the granaried heap or cargo of corn, unless the weather is very hot; they then are specially lively on the outside.'

'Although these granary weevils are the most destructive enemy to stored corn, they leave sound what they do not actually attack. This is not so with that other great enemy, the wolf-moth (*Tinea granella*, L.) which spoils more than it eats, by spinning the grains together with its dirty silken web, and thus becomes a more troublesome pest, perhaps though less destructive than the Calendra. In all weevily corn, the snouted unicolorous *Sitophilus granarius*, and the *Sitophilus oryzæ* which has two red spots on each wing case, will be conspicuous as the most abundant and most destructive insects. As far as my own experience goes *Sitophilus oryzæ* is by far the commoner of the two.'

'The increase of these Calandridæ and their allies is naturally limited by internal hymenopterous parasitism. I have met with two (probably three) species of Chalcididæ, and Curtis knew another. About a dozen *Cerocephala formiciformis*, Westwood, or a very closely allied species, were bred.'

'To return to the actual economy of the *Sitophilus*, the two species are so closely allied that, practically, they may be considered as one. It has been usually supposed that the parent weevil bores with its rostrum into the grain previous to depositing its egg in the hole made. I do not believe this is the case, for a very fine puncture only, such as would be made by a very fine needle, is to be seen on the borders of the germen in those grains which contain the larva. The egg is, therefore, laid, I think, just on the surface, as Olivier says, or under the outer skin of the germen, and the young larva eats its way in. One egg only is deposited in a grain, the flour of which just serves to bring the larva to maturity. It turns to pupa in the grain, so that, unless very minutely examined, affected grains are not apparent until the emergence of the imago, except by their weight. The imago partially feigns death when touched, and on a tolerably smooth surface, such as a

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paper or a painted board, can travel at the rate of about one foot per minute. How many broods there are in Britain it is difficult of determination; it probably depends on many varying circumstances as to degree of warmth and the like, but the normal number is probably two annually. I have found the larva both in early summer and in late autumn. The rapidity of development also varies greatly. Hybernating imago, egg laid in May, second generation in August, is probably approximate for Britain in an unheated store-room. The only corn I have known attacked is wheat, barley, and maize; it does not touch oats, rye, canary, peas or beans. In the larval state only one grain is destroyed by each insect, but it is probably much more destructive as an imago; and the beetles, which survive great extremities of temperature, appear to be remarkably long-lived. Amongst some maize taken in 1876 affected with *S. granarius*, and in which I believe it has not bred, I have a quantity of specimens still (November 1878) alive. It seems to breed very sparingly in this country, for when in want of a larva or pupa I have opened some hundreds of kernels from my stores without finding one.'

With regard to remedies, Mr. Fitch says:—'Cleanliness alone will do the required works and this requires to be thorough to cope with such a crevice and cranny loving, hybernating insect as the Calandra. Frequent lime-washing and scrubbing (with soft soap) of granaries, the plastering of all uneven wall surfaces, the asphalting or concreting of all uneven floors, the free use of the dressing machine or blower, and frequent sifting or turning over of the grain, are the only likely remedies against weevil attack. It is also necessary to guard against mixing sound wheat with any containing "weevil," except for immediate grinding; also to see to the destruction of all rubbish and tail corn in which it is possible for the beetles to live or breed.'—*From a paper by E. A. Fitch, "Entomologist," Volume XII, 1879, page 41.*

Miss Ormerod found the increase of *S. oryzæ* to go on slowly and, apparently, with even more dependence on genial surroundings than that of *S. granarius*. 'In general appearance and in size the two weevils are very similar, but the rice weevil is easily distinguishable by the two orange-coloured patches on each elytron, and also by the possession of wings, from the uniformly tinted granary weevil, wingless in this country. On 5th September 1877 I received a packet of the sweepings of corn ships, known as "Indian dust," literally alive with these rice weevils from imports from the East Indies. On September 6th the beetles were pairing, and on placing them within reach of warmth from the fire they became very active, but during the rest of the experiment I kept them merely at the ordinary temperature of living rooms constantly used. After this I noticed no further advance, till on the 9th March of the present year, when on examining some of the corn amongst which the weevils were placed on the previous 5th September, I found numerous wheat grains, now each containing one larva, and there were also a very few pupæ; the latter, however, all dead in different stages of development. The thick fleshy grubs were now from a sixteenth to somewhat under an eighth of an inch in length when at their full stretch, but somewhat less in their usual curved position, and their breadth about two-thirds of their length. The grubs obtuse, legless, and white; the head chestnut colour; jaws also chestnut, darker at the extremity, bluntly pointed, and waved into two blunt teeth. The segment behind the head and the candal extremity with a few small bristles. The movements of the larvæ during life, and their contorted form after death, made it difficult to sketch them satisfactorily, but the figure represents a specimen fairly with the numerous corrugations which confuse the primary segments with the lesser folds, the underside being a complete mass of almost scale-like corrugations.'

'A few pupæ were now (March 9th) observable, but only two specimens were as fully developed as the one sketched, and on 11th April the larvæ were active when disturbed in their grains, but no more pupæ were produced.'

'On 3rd June I found only two more beetles, and on examining the grains of wheat I found one grain in ten with a tenant in some stage of development, for the most part still only in larval form, and often stunted. A few grains contained specimens of the weevil in its perfect form, but for the most part they were small, distorted, and dead. As

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no further progress was observable during the course of the summer, I made a selection of infested grains, but did not examine them particularly again till about 26th October, when I found numerous beetles, but still not by any means corresponding in number with the infested corns of wheat, and the larvæ were still to be found in the grains, and some beetles only about half the ordinary size, and differing in markings from the normal type. In the healthy specimens the colouring was as in the characteristic types, the wings were properly developed, and in one case I noticed an attempt at flight; but as far as one experiment goes, the slow rate of development which in thirteen months has only given one brood, and that not as numerous as the parent weevils, shows the effect of unfavourable climate or surroundings in materially retarding multiplication.'—(*From Miss Ormerod's paper in "The Entomologist," Volume XII, 1879, page 51, from which also the figures of the larvæ and pupa have been taken.*)

Miss Ormerod quotes from Professor C. V. Riley's paper in the March number of the *Farmers' Review*, Chicago, regarding the position of the egg of *Sitophilus oryzæ*:—

"The puncture is somewhat curved, rather less than $\frac{1}{16}$ inch deep, and rather narrower at the bottom than at the opening, the egg, which is 0·5 m.m. long, elongate, ovoid, and translucent, is pushed to the bottom, and the whole space above it is then filled in with particles of grain gnawed into fine powder-like flour, the orifice being pasted over with a little saliva." 'Professor Riley's article gives much practical information, but from my own observations of the habits of this and the closely allied species *S. granarius*, I should like to add to the remedial and preventive suggestions the plan of trapping by setting vessels of water, as far as experiment with the pest in one badly-infested granary can be trusted; the weevils would, in this way, be attracted from the corn in enormous quantities, and easily destroyed by throwing the stupified insects into the fire.'—(*From "The Entomologist," Volume XII, 1879, page 207.*)

'*Sitophilus granarius* (the wheat weevil, or charançon du blé). Abdomen with uncovered extremity, antennæ elbowed and provided with a club, dark brown in colour, three millimetres long. The thorax is the same width as the elytra, and forms almost half the body. The elytra are slightly rounded at the extremity, and covered with longitudinal furrows.'

'This weevil causes much damage in granaries. The beetles appear in the end of April and beginning of May. Then commences the laying of the eggs, which would be prevented if the temperature happened to be eight or nine degrees Réaumur lower than usual at this season. The female after being fertilized enters a heap of grain, penetrating into it some five or six centimetres, so that she may be undisturbed; she then chooses the grain in which to lay her egg, cutting in it a small hole with her mandibles, generally on the groove where the skin is most tender, and as if to better hide the spot where she has laid the egg, she cuts the hole somewhat obliquely and covers it with a secretion of the colour of the grain she attacks, so that even an experienced eye cannot discover the hole.'

'In this manner she attacks a series of grains, the number of them being the same as that of the eggs she has to lay.'

'The egg laid in the grain hatches without delay: and from it comes forth a little larva, white, produced, soft, with body composed of nine segments, with a horny head, armed with two strong mandibles, by the aid of which it enlarges each day its residence, nourishing itself on the farinaceous substance of which its habitation is composed. When full grown the larva is about 3 m.m. in length, and it then enters into the pupal state. After reposing as pupa for eight or ten days it transforms into the perfect insect which is capable of perpetuating its destructive race.'

'The time occupied in development depends on the temperature, heat accelerating, and cold retarding it considerably; an average time from the deposition of the egg to the emergence of the perfect insect is 45 days.'

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'Bory de Saint Vincent says that, according to Dégeer's calculation, a single female in one year can produce 23,600 individuals; another estimate gives 75,000 individuals as the offspring of twelve pairs of weevils in a hectolitre of grain, each of which would consume three grains in the year for its own subsistence, or about 12 per cent. Other naturalists confine their estimate of the offspring of twelve pairs to about 6,000. This last figure, however, abundantly suffices to confirm the worst fears that the farmer has of his enemy.'

'The grain, whose interior is devoured by the weevil larva, is not in any way changed outwardly; it is in fact impossible to distinguish it from the sound grain: if, however, one puts it in water it swims, while sound grain sinks.'

'The males live but a few days after they have fertilized the females. The female lives until she has done laying her eggs, and as she has many eggs to lay, she lives longer than the male; if there is no grain in which to oviposit she becomes torpid, waking up however when grain is supplied, being probably revived by its odour, she then lays her eggs and dies.'

'It is thus specially in the larval state that the weevil is injurious to the grain. The only perfect insect that devours it being the female engaged in oviposition, an operation which goes on throughout the whole of the summer, until the cold deprives the insect of the necessary activity. The beetles then quit the heap of grain, and seek shelter in the holes in the walls, and in the cracks in the floor, where it is difficult to discover them: with the first warmth of spring they appear to again copulate, oviposit, and die.'

'The odour of many vegetable substances, such as hops, elder flowers, rue, lavender, and coriander, is objectionable to the beetles and makes them quit the wheat; also decoctions of these plants and also of ivy, box, and larkspur, spread through the granaries, produce the same effect. Valmout de Bomare, however, considers all these methods useless or impracticable; Duhamel also has found that the beetles live quite contentedly in wheat, enclosed in a case that had been painted with oil of turpentine; according to Duhamel sulphur in vapour is the only thing to destroy the beetles, and this gives a flavour to the wheat.'

'In some provinces of France millet seed is mixed with the wheat, as the insects attack millet seed in preference to wheat, so that by later sifting out of the millet seed, which is smaller than the wheat, the beetles are got rid of.'

'Stirring the grain, and aerating it, by means of forcing air through tubes in the heap of wheat, are recommended, on the ground that the insect loves warmth and quiet. The most effectual method of cure is, however, to destroy the affected wheat and to put hay into the granary.' Mons. Menault asserts that now that grain is less stored than before, the ravages of the insect are becoming less serious.—(*Translated from the account given by Ernest Menault, in his "Insectes Nuisibles à l' agriculture," Paris, 1886, page 8.*)

'*Sitophilus* (*Curculio*) *granarius*, Linn.—(Der Schwarze Kornwurm). Beetle attacks rye, wheat, and maize. Introduced from the East, it probably acclimatised itself in Southern Europe, of which, however, nothing is known positively; in Germany it only appears in granaries, mills, bakehouses, &c.; sometimes in immense numbers.'

'The beetle is red to black brown in colour, antennæ and legs somewhat lighter (rust red); length, not including the proboscis, is 1¾" breadth ¾"; the thin slightly curved proboscis is about the same length as the thorax, and bears at its base, immediately in front of the eyes, the elbowed antennæ with six jointed stock, and long egg-shaped, indistinctly jointed terminal club. The thorax is longer than broad, slightly narrowed in front, flat above, and beset with large produced dots, which leave, however, a smooth longitudinal medial stripe. Elytra are, together, the same width as the thorax, at the outside a third longer than their combined width, with parallel sides, rounded off at the posterior end, and not covering the posterior plate of the abdomen, flat above, deeply striated with pits, the intermediate spaces being smooth. Tibiæ each terminating in claw, the front ones having small notched teeth on the inner edge. Tarsi four-jointed.'

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'The corn-worm must not be confused with the very similar rice weevil (*Sitophilus oryzæ*), which is dull and pitch black in colour, has one spot on each shoulder of the elytra, and another a little behind the middle, which, as also the lateral edges of the elytra, are reddish in colour.'

'The thorax is very closely punctured, the pits being deep and round, scarcely leaving a medial line clear.'

'The wing covers very thickly striato-punctate, the narrow spaces between each row of puncture being coveredwith short yellow bristles.'

'The larva of the corn-worm is like all conculionid larvæ, footless, curved, swollen, white in colour, with horny head, brown towards the mouth parts: it inhabits a single grain and devours it little by little till only the husk is left; in the case where this grain is not larger than an ordinary grain of rye, it lies wedged inside, cramped by its own excrement which, however, has no unpleasant smell.'

'The larva becomes full fed and transforms into a colourless, slim pupa in the same grain in which the egg was laid. The two front pairs of legs lie with their tibiæ and femora outside the wing covers, the last pair of legs appearing from underneath towards the extremity of the wing covers.'

'About five or six weeks after the egg is deposited, the beetle eats its way out of the grain, generally about the beginning of July. After about a fortnight this generation begins copulating; then the female bores a hole with its rostrum in the grain, in which it lays a single dirty white-coloured egg. From this egg is developed, in the end of September, the second generation, which, according to the temperature, either feeds a little longer, or else hides itself for its winter sleep in cracks, under beams in the threshing floor, and such like places, wherever it can find shelter from the frost. The following spring, the insects wake up, and collect on warm sunny places, beginning to copulate and commence a new round of life as in the preceding year. It seems not improbable that in warm seasons, and especially in southern countries three generations may be gone through in the year, and that in cases where they are undisturbed, each generation will be very much stronger in numbers than the one which preceded it.'

'It is supposed that one female will lay as many as 150 eggs; and it appears that she lays these eggs, not all at one time, but extending over several weeks, about which, however, I have no exact information. This much, however, is certain, that whenever the corn-worm appears, it and its larvæ are very destructive, and become more and more so by multiplication if no measures are taken to master them.'

'I should add that the insects love warmth, collecting specially on the south side of the granary, and that it therefore seeks close, unventilated places, and attacks most readily grain that was not thoroughly dry when brought into the granary. The insect also prefers old wooden buildings, as in them it finds most suitable shelter for hybernating. It is very gregarious, and lives in large swarms, is very active on its legs, but is unable to fly. Heaps of badly weeviled grain have so high a temperature that it is perceptible to the touch.'

'From the above particulars many remedies immediately follow. The granary must be airy, clean, and all cracks in it filled up. In the case of having to deal with larvæ or pupæ, the only thing is to heat the grain in ovens, if one cannot grind and use it without delay; for as both of these are completely shut up in the grain, they can only be destroyed by heat. The most important thing is to capture the beetles in masses at the right moment. This moment being before the females have laid their eggs, that is to say, in the spring, when they come out of their winter quarters and collect on suitable places; a second time in the beginning of July, when the first generation appears in even greater numbers than its predecessor; and finally in the beginning of September when the last and hybernating generation of beetles appears, when, of course, the measures are only useful for the following year. When the beetles are found in the heaps of grain they must be driven out by sifting. Dry rags should be spread in the places to which the beetles naturally tend, that is to say, towards the south side of the floors, as it is found that they readily take refuge in them, and should then be carefully destroyed, by hammering the rags, or by burning them or immersing them in boiling water.'

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'It is also a question, which is worth considering, as to whether, on cold days which are certainly trying to the insects, warmed areas might not be utilised for attracting the insects so that they might be destroyed. These warmed areas might easily and safely be made by means of fire bricks or hot sand, each warmed area being covered with rags, and in this way regular traps constructed.'—(*Translated from Dr. Taschenberg's "Naturgeschichte der Wirbellosen Thiere," page 63, Leipzig, 1865.*)

Calandra (*Sitophilus*) *granaria*.—'This pest has been introduced from the East, and requires a more uniform or a higher temperature than do native species of Germany; hence, at least in Germany, it is not found in the open but in granaries and other closed spaces, where the larvæ devour rye, wheat, and maize.'

Calandra oryzæ, Linn.—'This weevil has a similar life history to *C. granaria*; it is found in rice, but also attacks other grain, as in the year 1847, in Wurtemberg, when it was observed in maize, wheat, and barley, having been probably introduced from Egypt.'

Dr. Taschenberg adds an account of both species which, however, does not appear to contain any fresh observation.—(*Translated from Dr. E. L. Taschenberg's "Praktische, insektenkunde,"—Bremen, 1879, Vol. II, page 172.*)

'A high, airy, light building, careful cleansing of the granary floor, the filling up of all crannies and cracks with lime, the removal of all old grain that has accumulated even in very small quantities in the corners; constantly turning over the grain, especially in the spring and in July, will obviate, or at least lessen, the damage done by *Sitophilus granarius*. —Drying the grain in small quantities in an oven, kept at a temperature of 41° R. (about 125° F.), is a sure method of destroying the larva and pupa of this beetle, as also of the grain moth (*Gelechia cerealella*), though it is not easily applicable to large quantities of grain.'

'Attacked grain should be removed as soon as possible from the granary floor, or should be ground up into meal'; in which case, however, the meal must be used as soon as possible, as it does not keep well.' *Translated from Gustav Künstler's work "Die unseren kulturpflanzen Schädlichen insekten." Published by the K. K. Zool. Bot. Gesellschaft Wien, 1871.* Künstler also gives an account of the insect which, however, does not appear to contain anything new.

'In attacked grain no external sign is to be seen, but on putting one's hand into the heap, one feels that it is distinctly warm.' An account of *Calandra granarius* is also given, which, however, does not seem to contain anything new.—(*Translated from Schmidtgöbel's work "Die Schädlichen und nützlichen Insecten in Forst Feld und Garten," Vienna, 1881, p. 175.*)

Damian Kompfe in his "*Naturgeschichtliche Aufsatze über Freunde und Feinde der Landwirthschaft*," *Leipzig and Mainz, 1879, p. 108*, says that the development of *C. granaria*, from egg to perfect insect, can be gone through in four weeks. Recommends using an infested granary for hay only, for a year, when, he says, it will be found to be free from the pest, or even simply cleaning it out and filling it up with new hay between the hay and wheat harvests, he says, is effective. He recommends smearing the beams and wood-work of the granary with coal tar, or even merely painting loose beams with it, and scattering them over the floor to drive out the insects from their retreats.

'Herr Grimm notes that *Calandra* (*Sitophilus*) *granaria*, Linn., does great damage to the grain upon the fields, in the government of Saratow. This, however, requires

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confirmation as, so far as is known, this curculio resides in granaries and threshing floors alone and never attacks growing grain. With us damage has been observed to be done by it in the granaries of Riga Krementschug and in Neu Rusland.'—*Translated from Köppen's work, "Schädliche insekten Russlands," St. Petersburg, 1880, page 228.*

Mr. Mills discusses damage done to wheat in Madeira by *C. granaria*.—He says that it is impossible to discover the puncture made in depositing the egg in the grain, even grains containing pupæ being externally quite intact. 110° F. was found to be the best temperature for hatching the insect; 130° to 140° F. being fatal to them. He describes a room heated with hot water pipes, in which 800 bags of wheat could be received at a time, the whole being heated to 135° F. The wheat after this treatment is resifted, when it is found to be quite free from weevils, and makes as good bread as before, the germinating powers of the grain being uninjured. The heating action of weevils, when taken internally, which resembles that of cantharides on a slow scale, is also commented upon —(*Trans., Ent. Soc., Lond., Vol. I, p. 241, 1836.*)

Walsh and Riley (*American Entomologist, I, p. 179*) record Dr. Hartman's statement that in South American States *S. granarius* has been used successfully as a substitute for cantharis in blisters. (*Not seen.—E. C. C.*)

H. J. Cromstock (*United States, Department of Agriculture, Report, 1880, p. 270*) gives a description of a small steel blue coloured chalcid parasite, with large red eyes (*Pteromalus calandræ*, Howard) which attacks the weevil.

"The fate of the produce may assist in illustrating the effect of the weevil. The different grains, after being gathered, were put into baskets, and kept within my own house for a few days, while new earthen pots were being made to preserve them in. When the pots were ready, the grain was well dried in the sun and put into them, the covers of the pots being closed with a lute of fine lime. Notwithstanding these precautions, I was surprised to find, on opening the pots after the rains were over, that four-fifths of the grain had been destroyed by the weevil. Their contents really appeared to be alive with the myriads of these little creatures which were running about. I have been much puzzled to account for the generation of these insects in the case described. It appears confirmatory of the idea prevalent among the natives, that they are bred in the interior of the grain, the eggs being laid in the blossom. At the same time I have observed or learned several facts which seem to militate against this idea; oats which have a hard husk, are never touched by them; barley, which has also a husk, but a softer one, partially suffers from them, but is less readily attacked than wheat; the huskless barley, on the other hand, suffers quite as much as wheat; paddy, or rice with the husk on, is quite free from their depredations, but white rice being deprived of the husk is often much injured by them; and the seeds of the maize, when left on the cob, are rarely or never touched by them; but if plucked off, leaving exposed the soft side underneath, are very often entirely destroyed by them. These facts seem to show that they are not bred in the interior of the grain, but make their attacks from the outside."—(*From T. H. Bridgman's paper, on experiments with wheat grown at Gorruckpore, published in the Journ. of the Agri.-Hort. Soc., India, Vol. III, Appendix, p. 88 (1844).*)

"The leaves of the *Melia azedarach*, or, as it is called in America, the pride of India, or China tree, called "*neem*" in Hindustani, is a sure preventive, and is universally used in the

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Southern States of America. All that is required is to put a few of the leaves in the barn with each wagon-load of corn, whether maize or wheat, and to scatter some of the leaves between each tier of sacks of grain when loading a ship. This is pretty generally known and extensively used in some districts of the N. W. P. of India. I observed it in the district of Cawnpore, where the people preserve their grain in large pits made in the ground: which will contain from 300 to 500 maunds." A suggestion is made of mixing thoroughly half a bushel of blown salt with one hundred bushels of wheat as a preventive, and an account of the species *Calandra granaria* and *C. oryzæ* is appended.—(*From Agri.-Hort. Soc., Ind., Vol. V, Appendix, p. 147 (1846).*)

'On the banks of the Nerbudda wheat is kept in *bundehs* or pits containing over 500 to 2,500 maunds. They are shut up soon after the harvest, and covered over with earth. If unopened the grain keeps without being attacked by any insects, or becoming tainted, for several years; a high place is always selected for a *bundeh* which is sometimes thatched.'—(*From a paper by Colonel Ouseley, Journ., Agri.-Hort. Soc., Ind., Vol. VI, Appendix, p. 148 (1848).*)

A letter, reprinted from the pages of the *Economist*, giving an account of the protection of grain from weevil by keeping the granary dry.—(*Journ., Agri.-Hort. Soc., Ind., Vol. VI, Appendix, p. 148 (1848).*)

An account of *Calandra granaria* is given in *Griffith's Animal Kingdom, class Insecta, Vol. II*, quoted at length in *Journ., Agri.-Hort. Soc., Ind., Vol. III, Appendix, p. 139 (1884).*

References are given by Westwood in his *Modern Classification of Insects, Vol. I, p. 847 (1839)*, to the following papers on *Calandra granaria*:—

Kieferstein in *Silbermann's Revue Entomologique, No. 9.*
Latreille *Hist. Nat., Vol. XI, p. 54.*
Kirby and Spence's *Introd., Vol. I, p. 173.*
Gardener's Mag., Vol. I, p. 444.
Bulletin de la Soc. Philomat. for 1826.
Various memoirs referred to by Dryander, *Cat., Liber. Banks, 236, 237, 544.*

Papers on *Calandra granaria* from the *Gardener's Chronicle*, December 30th, 1843, and August 3rd, 1844, are quoted at length in *Journ., Agri.-Hort. Soc., Ind., Vol. III, p. 144 (1844).*

A paper in *Journ., Agri.-Hort. Soc., Ind., p. 4, Appendix, page 29*, on wheat weevils, by G. S. Mercer.

In the "*Standard Natural History*," edited by T. S. Kingsley, Boston, 1884, *Calandra oryzæ* and *Calandra granaria* are said to be distributed throughout North America. *Calandra oryzæ* is said to attack rice, wheat, and corn, ovipositing on the rice when growing.

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In the *Trans. Ent. Soc., Lond., 1870, Proceedings, p. 15,* is an account of Spanish wheat attacked by *Calandra oryzæ*; also of American maize attacked by the same insect. From 74 tons of the former 10 cwt. of weevils had been screened; from 145 tons of the latter 6 cwt. and afterwards 79 cwt. of weevils were screened out.

Carl Vogt in "*Vorlesungen' über nützliche und schädliche, verkannte und verläumdete Theire,*" Leipzig, 1867, p. 143, gives an account of *S. granarius* with figures of the larva, pupa, and imago, containing however nothing not already fully dealt with in other extracts.

Künstler in *Verhandl. Zool. Bot. gesell. Wien, Vol. XVII, 1867, p. 928,* gives an account of *S. granarius.* His account contains, however, nothing not already dealt with.

M. H. Lucas in *Ann. Soc. Ent., France, Ser. V, Vol. X, 1860, p. 32,* notes having found *Calandra oryzæ* in cases which had contained food during the siege of Paris.

Ann. Soc. Ent., France, Ser. IV, Vol. IX, 1869, Bull., p. 16, contains a note on *Calandra oryzæ* affecting a seed of *Nebulium.*

Duncan, "*Transformation of Insects,*" London and New York, gives a short account of grain weevils, figuring both *Calandra oryzæ* and *Calandra granaria.*

M. Maurice Girard, in *Ann. Soc. Ent., France, Ser. VI, Vol. II, 1882, Bull., p. 127,* remarks on grain attacked by *Sitophilus granarius* in Paris Granaries.

W. Scriba, *Stett. Ent. Zeitung, 1857, p. 377,* records finding very narrow specimens of *S. oryzæ* under bark of cut elm trees.

Olivier, *Entomologie Coleopt., Vol. V, Paris, 1807, pp. 95-97, pl. 16, fig. 196, a—b, and pl. 7, fig. 81, a—b,* describes and figures both *Calandra granaria* and *Calandra oryzæ.*

Du Val and Fairmaire in "*Genera des Coléopterés d'Europe,*" Paris, 1868, Vol. IV, p. 69, pl. 29, fig. 140, gives a description and figure of *Calandra granaria.*

In the *Dansk. Vid. Selsk, Skrift. II, p. 56 (1783),* is a short notice of *Curculio granarius.*

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Gemminger and Harold in their "*Catalogus Coleopterorum*," Vol. VIII, p. 2653 (1871), give the following synonyms and references to these two species :—

CALANDRA GRANARIA—

granaria, Linn. Syst. Nat. Ed. X, p. 378.
Panz. Fn. Germ. 17, 11.
Gylh. Schh. Gen. Curc. IV, p. 977.
Jac. Duv. Gen. Col. Curc., 1854, pl. 29, fig. 140.
Frisch. Besch. All. Ins., 1720, II, p. 36, fig. 8.
pulicaria, Panz. Ed. Voet. IV, p. 54, pl. 37, fig. 17.
segetis, Linn., loc. cit., p. 381.
unicolor, Marsh. Ent. Brit., p. 275.
Steph. Ill. Brit., IV, p. 9.

Habitat, South Europe.

CALANDRA ORYZÆ—

oryze, Linn. Amœn., Ac. VI, 1763, p. 395.
Oliv. Ent. V, 83, p. 97, pl. 7, figs. 81, *a—b*.
Gylh. Schh. Gen. Curc. IV, p. 981.
Scriba, Stett. Ent. Zeit., 1857, p. 377.
Kollar, Sitzgsb. Wien. Ac. 1848, V, p. 3.
frugilega, Degeer, Mem. V, p. 273.
granaria, Stroem, Dansk, Vid. Selsk. Skrift., II, p. 56.
quadriguttata, Montrouz. Ann., Fr. 1860, p. 910.

Habitat, Java, South Europe, South America, India, Lifu.

The following series of practical accounts of the wheat weevil has been obtained by Messrs. Ralli Brothers of Calcutta from their different Agencies, in answer to a series of questions addressed to them in January 1888 :—

CALCUTTA,
The 26th January 1888.

1. The percentage of loss known to be caused by the weevil in granaries is as follows :—

Maximum	. . . . .	5 per cent.
Minimum	. . . . .	1 „
Average	. . . . .	2½ „

2. The soft varieties of wheat are more affected than other varieties.

3. Delhi, Buxar, and Hanskbally wheat is more affected than wheat from other localities.

4. The pest commences from July in Lower Bengal and August in up-country, and does more damage from September. From the beginning of the crop till the latter end of June wheat remains almost free from the attack of weevils.

5. The weevil attacks rice and maize besides wheat.

6. The wheat weevil is found nowhere besides in granaries.

7. To the best of our belief the only remedy employed against the weevil in India is exposure to the sun. With regard to the remedies mentioned we cannot express an opinion. We only wish to remark that ventilation causes the grain to be more infested by weevils, as wheat, packed in bags, gets more weevilled than wheat stacked in bulk or pile which is more air-tight.

8. We believe that sparrows, crows, and other birds destroy weevils.

9. We are not in a position to answer the question of how many generations there are in the year.

10. There are four species of insects infesting edible grains, of which two kinds are found to attack rice; and again one species out of these two attacks wheat and maize, and two kinds infest pulses.

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BUXAR AGENCY,

The 13th February 1888.

Wheat Weevils.

We beg to reply to your questions regarding wheat weevils as follows:—

1. Soft wheat is more easily attacked by weevils than other varieties.

2. Weevils attack wheat everywhere, but in districts where wells are not in use the damage done by weevils is greater.

3. Wheat thrashed in March is not attacked by weevils till about early in June. At this time the wheat is quite dry. When old weevilled wheat gets mixed with fresh wheat, the insects will attack the former only.

4. We have found that most damage is done after the rains. The wind which succeeds the monsoon is favourable for the propagation of the insects, whilst by the middle of February most of them die. From March to May wheat is almost free from weevils.

5. Wheat weevils attack also all other kinds of grain except oilseeds.

6. Wheat weevils are found in granaries, and in any place where grains are kept. If grains are kept in bags, in the open, the weevils will attack the contents.

7. The best remedy is the system of preserving wheat in wells, used all over India: a hole is dug from 16 to 20 feet deep and from 10 to 12 feet round; this is filled up with wheat except the top; the bottom and the sides are stuffed with "Boossa," minced straw; the top is covered with earth formed in a heap, 3 feet above the ground, to protect the wheat against rain. In this way the grains are never attacked by weevils, as long as the well is air-tight.

Grain kept in bags are attacked more easily and suffer far more damage than grain kept in heaps, as being more exposed to the air.

Grain kept in a heap, in a pucca godown, perfectly closed and filled up to the top, will not suffer much damage. The weevils will attack the grain all round the walls and at the top, but will not attack the central part as it is air-tight. When wheat is kept in heaps, the larger the heaps the better.

Spreading wheat to the sun and stirring it once or twice will make the weevils leave it.

Weevils avoid the sun, consequently in spreading out the grain it must not be thicker than ½ of an inch, otherwise the weevils, instead of leaving the grain, will remain underneath it.

Samples of grains kept in boxes are not attacked by weevils, if kept with camphor.

8. We do not know of any insects that destroy the weevils.

PATNA AGENCY,

The 13th February 1888.

Wheat Weevils.

In answer to your letter, dated 25th ultimo, we beg to say:—

1. Soft wheat is sooner affected by weevil than hard.

2. Wheat is more affected in some districts than in others.

3. We find that it is during the rains that most of the damage is done by weevils, and that wheat is entirely free from attack before the rainy season.

4. Weevils attack grain only, *i.e.*, wheat, maize, pulse, &c., but do not attack seeds.

5. Weevils attack grain everywhere except in underground granaries (local term, khad).

6. So far as we can learn, there are no other remedies employed out here, except the above (khad).

None of the remedies mentioned by you in page 2, No. 6, *a*, *b*, *c*, *d*, *e* are employed against weevil out here. We do not know of any insects or other animals that destroy weevils.

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CAWNPORE AGENCY,
The 29th January 1888.

Wheat Weevils.

In reply to your favour of the 25th instant, we now beg to send you all the information we could obtain and what we know on the subject from personal experience.

We may first mention that there are two different kinds of weevils attacking wheat—

1.—A small one, called by the natives "Chun," only works superficially, *i.e.*, attacks the outside of heaps and hardly ever goes deeper than an inch into wheat in bags; it also attacks the grain near the gunnies only.

The other weevil, called by the natives "Paie"[1] (which is comparatively rare), penetrates right into the middle of a heap or of bags.

The "Paie" is nearly double the size of the "Chun," and we were always under the impression that one was the male and the other the female; we have been informed, however, on good authority, that this is not the case; that in fact both weevils are not usually found together.

We will now reply to your questions in rotation—

1. We know of no varieties of wheat that are more or less affected than others.

2. The weevils appear in all districts to be the same.

3. Weevils are not perceived before the rains, as a rule, and hardly any damage is done by them before about beginning of August.

We do not mean, however, to say that the rains bring the weevils, or have anything to do with their appearing; allwe maintain is that the wheat is free from weevils, when fresh, and only when the grain gets comparatively dry, the weevils put in an appearance.

4. The wheat weevils attack gram, maize, and other coarse grain, but no oilseeds.

5. Wheat weevils have never been observed anywhere else, except where grain is stored.

6. As for remedies employed against weevils, there is one most efficient used by natives, which is, to keep the wheat and grain, they do not sell, in granaries underground closed air-tight. In that manner wheat is kept by natives for years and years, without being attacked by weevils of any kind. In fact, wheat with weevils, if put into a pit and closed air-tight, in the way the natives do it, will keep equally well for an unlimited number of years, the weevils dying at once.

That the weevils require air, is proved by the fact that dealers, for instance, when they have a quantity of wheat on hand, store it in heaps and never disturb it. Later on they find only the upper strata, to the depth of about ½ inch with weevils; this is carefully taken off and the rest of the wheat is hardly damaged at all.

Often they cover the heap with fine cut straw, and maintain that the weevils then only attack the uppermost grains of the heap—

(*a*). Ventilation and stirring the grain about appears to develop the pest.

(*b*). Nobody here ever heard of traps.

(*c*). Cleaning the grain, the ships and buildings, filling up cracks and crannies, may do some good, for the time being, but the moment wheat is stored again in the place and left there, weevils will, after some time, appear on the surface.

(*d*) & (*e*). No remedies are known here except those mentioned above.

Natives do not care and do not bother their heads about weevils, knowing that in their air-tight pits underground, nothing will attack the grain.

Whenever grain is required they open a pit, take out what is wanted, and close it again.

(*f*). There is no insect or other animal known that destroys weevils.

Upon the whole, the natives all over India, as well as in other countries, go on the principle of shutting out the air, as much as possible, to preserve their grain and not stir it about.

[1] Probably a *Rhizopertha* beetle belonging to the family *Bostrychidæ* which is mentioned by Fitch (*Entomologist*, XII, p. 45) as occurring in wheat in England, and of which, or of an allied species, specimens have been found in Calcutta, in a sample of wheat kindly sent by Messrs. Ralli Brothers (E. C. C.).

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SAHIBGUNGE AGENCY,
The 31st January 1888.

Wheat Weevils.

The following is our reply to your favour of 25th instant about wheat weevils :—

1. Samally qualities are not only the first to be attacked, but also suffer more from the weevil than other qualities.

Doodhia is next ; whilst Gangajally and Gya, on account of their hardness, are not attacked to any great extent.

2. The North-Western Provinces suffer more than Bengal from the pest, but, generally speaking, there is not any considerable difference.

3. The weevil appears in July, but during this month and August the damage is not very great ; the following months, up to December, show considerable damage, more especially during November and December, when whole bags have been destroyed, not a single grain remaining unweevilled ; in January and February they begin decreasing, and in March the grain is almost entirely free from them.

New crop wheat, rice, and maize are quite free from weevil for the first three months of the crop, but this is on account of the grain being new and fresh.

4. The wheat weevil attacks rice and maize but never oilseeds.

5. It is found in the open, not being so prevalent in granaries in Bengal and some parts of Behar, which places follow the method as given in the next paragraph for the protection of grain in store.

6. The only method to prevent destruction of grain from the weevil (and which, we believe, is not followed to any great extent in the North-West) is to make the granary air-tight ; this is easily done, as holes are dug in the ground or round buildings of mud are erected, then the floor and walls have a coating of about 9″ to 1′ of bhoosy-wheat chaff and husk ; the wheat is then bulked in this, stopped with a thick layer of bhoosy and closed in air-tight ; the grain remains in this way for months without being attacked from the weevil, which attacks it directly the bhoosy is removed. It is in this way that cultivators keep their stocks in a fit condition for cultivation. Dealers and others seldom use this method, but simply store in bulk in their godowns, and consequently about three feet deep on the top of the pile is almost destroyed, whilst the lower portion is untouched ; this is accounted for as the wheat settled down becomes solid and practically air-tight.

Ventilation and stirring the grain assist the weevil in its ravages, as it loosens the grain and allows the weevil to work further into the pile.

Nothing is known to destroy the pest ; neither is there any insect or animal that kills it ; drying in an oven would prove but of a temporary benefit, as the grain would soon be attacked ; after the process was over and the wheat was warm, we find that grain considerably weevilled gets heated, especially the soft kinds, and at this stage the weevil completely destroys the grain.

As far as we are aware, there are but two methods for preventing destruction by the weevil, and they are the methods used by cultivators as mentioned above, or the substitution of sand for the bhoosy, which is necessary, as, if wheat is simply stored in the above way, and on the same principle but without the bhoosy or sand, the weevil will attack the grain, although not to such a great extent as if it were in a ventilated room.

JUBBULPORE AGENCY,
The 13th February 1888.

Wheat Weevils.

The following is the only information we can give you on the subject :—

1. The weevil is not, as a rule, observed in new wheat till the monsoon.
2. The damp warm air of the monsoon seems to be most conducive to the propaga-

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tion of the pest; hot dry air and very cold weather check their ravages, and if exposed to great heat or cold, they die.

3. The soft qualities of wheat, especially the soft red qualities, are, as a rule, more affected than the hard qualities; consequently districts producing soft qualities are more affected than districts producing hard qualities.
4. When once weevils appear in wheat, they do not, without the use of artificial means, become exterminated, but increase more or less according to the quality of the wheat and the temperature of the air as referred to above.
5. The weevil is found in the open as well as in granaries; in fact it is, as a rule, found to appear in wheat, wherever wheat is exposed to the air, subject to the foregoing conditions.
6. The wheat weevil is not found in any other grain here, but there is a somewhat similar insect found in gram, another in peas, another in moong, another in rice, and so on.
7. The only remedies against weevils we have heard of are—
   (*a*). Putting the wheat, when in a sound dry state, into pits, "bundas," hermetically closed to the air. This is the method most generally adopted in our districts, and we have personally seen pits opened after three years and the wheat to be in as fresh and sound a condition as ever.
   (*b*). Putting ashes on the floor of the granary; and the leaves of the "Neem" tree among the wheat; these do not seem, however, to have much effect so long as the wheat is exposed to the air.
   (*c*). Spreading the grain out so as to expose the weevils either to the heat of the sun, or to the cold night air in winter, which kills them.
   (*d*). We give the following extract from the June number of the *Indian Agricultural Gazette*: —

(Here followed Professor Church's memorandum which is given on page 6.)

8. Some kinds of birds eat weevils, such as sparrows, minas, wagtails.

An enquiry is about to be started, we believe, by Government on "The insect pests of India," and the subject of wheat weevils will doubtless receive its share of attention.

From L. O. HOWARD, Esq., *Acting Entomologist, United States Department of Agriculture Division of Entomology, dated Washington, D. C., 15th March 1888.*

In the absence of Prof. Riley I beg to acknowledge the receipt of your letter of the 29th of January, transmitting specimens of a beetle which is injuring grain. The specimens arrived safely, and the first glance shows that the species is *Calandra oryzæ*. Clearing up and disinfecting the granaries, filling up cracks and crannies and trapping the beetles in rags and wool are all very well as methods of ridding the granary from these creatures. It is, however, considered a very good idea here in America to establish a large "quarantine" bin into which all grain is put after receipt and disinfected by means of a little bisulphide of carbon. It is then removed and stowed away. The bin in question must be made as tight as is possible, and the method of using the bisulphide is to place a pound or so in a shallow vessel on top of the grain. The vapour of this rapidly volatilizing substance is heavier than air and sinks through the mass destroying all contained insects. Care should be taken in its use on account of its extreme inflammability. The airing which the grain will get in removing it from the bin will probably be sufficient to rid it of the odour. This remedy was first proposed by Prof. Riley in 1879. Hoping that this information will meet your case.

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NOTES ON ECONOMIC ENTOMOLOGY—No. 2.

THE

EXPERIMENTAL INTRODUCTION

OF

INSECTICIDES INTO INDIA

WITH A SHORT ACCOUNT OF

MODERN INSECTICIDES AND METHODS OF APPLYING THEM

BY

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CALCUTTA:

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THE EXPERIMENTAL INTRODUCTION OF INSECTICIDES INTO INDIA.

Amongst means of combating insect pests insecticides hold a very prominent place.

A vast amount of laborious experiment has been carried out in America on this subject, with the result that certain preparations have been perfected and methods and apparatus for applying them invented. In fact the great advance which has been made within the last few years in methods of combating insect pests has been to a great extent because the Department of Agriculture in America has succeeded in bringing before the public cheap and effective insecticides.

The insect pests of India are believed to be almost without exception allied to American ones, in some cases being actually identical with them, and there is every reason to presume that insecticides which have been found valuable in America will be also applicable in India, though much may have to be done in experimenting on each particular Indian pest and in devising the cheapest and most effective method of utilizing the American insecticides upon it.

The cost of the labour of applying insecticides being a very considerable item in the expense of using them, India with its cheap labour is perhaps more favourably placed with regard to them than is America itself, where, however, it has been found worth while both to invent them and to widely make use of them.

A short account of insecticides and methods of applying them is appended to show concisely how the question at present stands.

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A SHORT ACCOUNT OF MODERN INSECTICIDES, AND METHODS OF APPLYING THEM.*

Amongst a host of preparations, there are three chief and most generally applicable, which are being widely used in America and which are likely to prove useful in India.

They are—

(1) Arsenical compounds.
(2) Kerosene emulsions.
(3) Pyrethrum.

The first act through the stomach, and are effectual chiefly against mandibular insects; the second and third act by contact, and are therefore of more general application, affecting both mandibular and haustellate species.

Arsenical compounds.

Fifty grains of arsenitate of soda and two hundred grains of dextrin dissolved in a gallon of water, and diluted at the rate of about an ounce to ten gallons of water, furnishes one of the cheapest of insecticides at command, and various patented combinations of it are said to have been extensively sold and used in America. Again, one pound of arsenic and one pound of sal-soda boiled in one gallon of water till the arsenic is dissolved, and diluted at the rate of one quart to forty gallons of water, is also a good formula.

The chief merits of arsenic are cheapness and solubility. Its chief demerits are its white colour, which makes it liable to be mistaken for harmless substances, and its tendency to burn the plants.

Paris green (or Sheele's green) is said to have been more extensively used than any other arsenical compound. Dr. Riley first recommended it in 1872 for the cotton-worm, and its use gradually extended to other leaf-eating insects, until hundreds of tons are said to have been sold for insecticide purposes in a single year in America. It is used dry with various diluents, as ashes, plaster, flour, &c., at the rate of one part of the green (if pure) to twenty-five, up to one hundred, parts of the diluent. Flour as a diluent has the advantage of causing greater adhesiveness and permanence. In liquid suspension Paris green can be used at the rate of one pound to from 40 to 100 gallons of water. The liquid should be kept constantly stirred, and a little dextrin or other substance, added to give adhesiveness, is an advantage.

London purple, a refuse obtained in the manufacture of aniline dyes, is probably one of the most important arsenical compounds. It consists of lime, arsenious acid, and carbonaceous matter, and was first

* Compiled chiefly from the reports of the United States Entomological Commission, much of it being taken *verbatim* from an address delivered by Dr. Riley before the Georgia State Agricultural Society at Savannah in February 1884.

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used against the cotton-worm and other insects in 1878. It is used with diluents, either wet or dry, in the same manner as Paris green. While for some insects experience has shown it to be less satisfactory than Paris green, for many others it is equally effective, and has the great advantage over Paris green of being greatly cheaper (costing on an average but five cents against sixty cents per pound); of covering twice the ground, weight for weight; of being more soluble, less poisonous, more adhesive and permanent in its effects, and of decided colour, so that when intelligently used it is in all ways preferable.

Since the above was written in 1884 by Dr. Riley, the superiority of the London purple has been maintained, and it would appear to be the most generally useful of the arsenical compounds.

The following receipts, which have actually been used and found effective against various pests, are quoted as typical of the methods of applying arsenical compounds:—

(*a*) Forty gallons of water, ¼ to ⅜ of a pound of London purple (or ⅛ to 1 pound of Paris green), three quarts of flour, the solid ingredients intimately mixed with the water by washing them through a strainer, sprayed upon the trees by means of a force pump and San José nozzle, was found to effectively destroy web-worm. The effect of the poison is sometimes not observable until after three or four days, care must therefore be taken not to overdo the spraying.

(*b*) Bundles of cabbage, turnip leaves, or clover sprinkled with Paris green water and laid at intervals between rows, where cabbages have been sown, every three or four days, before the plants come up, attract and poison *cabbage cut-worms* before the crop to be protected appears above the ground.

(*c*) One part of arsenic, one part of sugar, six parts of bran, mixed together with a little water and sprinkled over the fields, has been found effective in clearing plantations of locusts (*Melanoplus devastator*) in California.

In the case of vines (seven or eight feet apart), about one teaspoonful of the mash is placed at the foot of each tree, which is then jarred to disturb the locusts. About ten pounds of the dry mixture is required for each acre, costing about 50 cents per acre, including the cost of application. This method of destroying locusts is chiefly applicable in orchards and gardens, where the insects are not very abundant.

(*a*) United States Annual Report of the Entomologist for 1886.
(*b*) Ditto ditto ditto for 1884.
(*c*) Ditto ditto ditto for 1885.

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Kerosine emulsions.

Petroleum, in its various forms, has long been recognized as one of the most effective insecticides known, all oily substances being particularly deadly to insects. Unfortunately, they are also injurious to plants, and probably one of the most valuable works of the United States Entomological Commission has been the discovery of methods of diluting them so as to kill the insects without injury to the plants. Refined kerosine has been used to a limited extent, by forcible attenuation in water and spray, while some plants withstand doses of the pure oil. But the safe and general use of kerosine for the purpose under consideration dates from the year 1880. Of the various substances used in attempts to emulsify and mix kerosine with water, none are more satisfactory than soap and milk, both being everywhere accessible and cheap. An emulsion resembling butter can be produced in a few minutes by churning with a force-pump two parts of kerosine and one part of sour milk, or soap solution, in a pail; emulsions made with soap solutions being generally found to be the more effective. The liquids should be at about blood heat. This emulsion may be diluted with from nine to fifty parts of water which should be thoroughly mixed with one part of the emulsion.

The strength of the dilution must vary according to the nature of the insect to be dealt with, as well as to the nature of the plant; but, finely sprayed in twelve parts of the water to one of the emulsion, it will kill most insects without injury to the plant.

A reckless use of any penetrating oil upon plants cannot fail to prove detrimental. Kerosene is, however, much less injurious than the lighter oils, naphtha, benzine, &c., with which in a crude state it is associated. The refined oil, such as is commonly used for illuminating purposes, is safer, and should generally be used in preference to the lower grades, which contain a large admixture of other oils, which are said to be exceedingly deadly to vegetation. The spraying should be done by a force-pump through cyclone nozzles,—the essence of successful spraying consisting in forcing the wash in a fine mist, allowing as little as possible to fall to the ground, and permitting each spray particle to adhere. It is best done in the cool of the day, and where possible in calm and cloudy weather; two or three sprayings at intervals of a few weeks being far preferable to a single treatment.

The following receipts, which have actually been used and found effective against various insect pests, are given as typical of kerosene insecticides:—

(*a*) Kerosene two gallons, common soap, or whale-oil soap, half a pound, water one gallon. The soap solution is added boiling hot to the kerosene, the mixture being churned by

(*a*) From Hubbard's Report on orange insects, dated 1885.

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means of a force-pump and spray nozzle for five or ten minutes. The emulsion, if perfect, forms a cream which thickens on cooling, and should adhere without oiliness to the surface of the glass. Diluted before using, one part of emulsion to nine parts of cold water. This formula gives three gallons of emulsion, and makes when diluted 30 gallons of wash; it has been used very successfully against scale insects on orange trees in Florida.

(*b*) Two parts of oil to one of soap solution or milk (the soap solution being made by dissolving from a quarter to one pound of common soap, or whale-oil soap, in one gallon of water). The whole is violently agitated at a temperature of about 100° F. by driving it backwards and forwards through a spray nozzle. The emulsion thus formed is diluted with nine parts of water. Flour or resin soap wash is sometimes added to the kerosine wash to give it greater adhesiveness; and four to six ounces of arsenous acid (or ½ pound of arsenic, ½ pound sal-soda, boiled in ½ gallon of water till the arsenic is dissolved; or half a pound of London purple) is sometimes added to each 100 gallons of the wash to render it more effective. This was used successfully against *Icerya purchasi* scale in California.

(*c*) Two or three ounces of flowers of sulphur added to each gallon of a wash (made as follows, kerosine two gallons, common or whale-oil soap half a pound, water one gallon) and applied in a fine spray is found to be the most effective combination against rust mite and scale insects on orange trees. It is best applied in early spring, and should never be used in mid-winter when there is danger from frost. The most effective sprayer for this purpose is found to be an aquapult pump and cyclone nozzles.

Pyrethrum.

Pyrethrum cinerariæfolium, a plant native to Dalmatia, has long been known to possess insecticide properties, especially in the powder from the dried and pulverized flowers. The species has proved to be hardy throughout the greater part of the United States, and Mr. Milco of Stockton, California, has for some years cultivated it extensively with considerable profit, the product being sold under the name of "Buhach." The insecticide properties reside in a volatile oil. It acts only by contact, and its action on many larvæ is said to be wonderful, a minute quantity in time paralysing and ultimately killing. Its influence in the open air is evanescent,

(*b*) Taken from United States Annual Report of the Entomologist for 1886.

(*c*) Taken from Hubbard's Report on orange insects, dated 1885.

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in which respect it is far inferior to the arsenical products; but being perfectly harmless to plants, it can frequently be used on vegetables where more poisonous substances would be dangerous.

Pyrethrum is supposed to have no effect on the higher animals. Dr. Riley's experience, however, is that fumes in a closed room have a toxic influence, intensifying sleep and inducing stupor; while the experience of Professor Bell, with the powder copiously rubbed on a dog, showed that the animal was made sick and was affected in the locomotive organs very much as is the case with insects.

The pulverized flowers are sold at about fifty cents per pound in America. The best method of using being to pour a quart of alcohol on a pound of the powder; leave it to stand for an hour and mix with forty or fifty gallons of water to be applied with a San José nozzle, or better to let the alcohol simply percolate through the powder and thus obtain a clear tincture, which can be applied with any nozzle. The powder may also be applied with bellows or mixed with water and applied by a pump.

Experiments will be made this year in growing the Pyrethrum in the botanical gardens of Seebpore and Saharunpore.

Other insecticides.

The following is an account of insecticides which are not so widely applicable as the preceding, but which nevertheless have been found useful against certain pests.

Bisulphide of Carbon still holds the first place in France against *Phylloxera vastatrix*; it is conveyed beneath the ground at the rate of half to one kilogram per vine, by special injectors, or by more complicated machinery drawn by horses. Dr. Riley believes, however, that kerosine emulsions will supersede it as an underground insecticide, and prove to be best, cheapness, safety, and efficiency considered.

Bisulphide of carbon is recommended* against the cabbage-fly (*Anthomyia brassicæ*), the maggot of which destroys the roots of cabbages and turnips. The bisulphide of carbon is used as for the grape phylloxera: a small hole is made in the earth near the main root of the plant, by forcing in a small stick, and about half a teaspoonful of the liquid is poured in, when the hole is quickly filled in with earth, which is pressed down with the foot. In every case where this was done the insects were killed without injury to the plants. In the use of bisulphide of carbon the extreme inflammability of its vapour must be remembered, and when much of it has to be used, a "Gastine injector," commonly used for the purpose in France, should be employed. As a safer and simpler remedy kerosine emulsion is recommended. Bisulphide of carbon has also been recommended for evaporation in shallow dishes on the top of grain stored in closed bins, for the destruction of the grain-moth (*Gelechia cerealella*). It has also been recommended by Professor Church for use against wheat-weevils.

* United States Annual Report of Entomologists for 1884.

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Napthaline and *sulpho-carbonate of potassium* are also of use against root-feeding or hypogean insects. Dr. Ernst Fischer has shown that naphthaline in crystal may be satisfactorily used underground, destroying by slow evaporation.

A wash made by allowing water to stand for several days in a shallow receptacle, in which a quantity of coal-tar mixed with a little oil-tar or oil of turpentine has been stirred until it becomes thoroughly impregnated with the odour, is found useful for washing cattle to protect them from the attack of buffalo-gnats (*Simulidæ*).

*A solution of *whale-oil soap*, one pound to ten gallons of water, is found useful against the rust mite on orange trees.

**Flowers of sulphur*, either dusted on the leaves or suspended in water and applied in spray, is also recommended as particularly fatal to rust mites on orange trees. A combination of whale-oil soap and flowers of sulphur is suggested.

Tobacco, *tobacco water*, and *tobacco smoke* have long been employed against aphides and other delicate insects, and are very useful. A recent advance is its use by vaporizing. The vapour of nicotine is most effectual in destroying insects wherever it can be confined, as in green-houses. Thus the boiling of tobacco in such green-houses is as effectual as the older method of syringing a decoction or fumigating by burning, while at the same time it is less injurious to the plants. The vapour gradually arising from tobacco stems strewn on the ground and regularly moistened has also been found to be effectual.

White helibore, either dry or in liquid, has been used satisfactorily against Tenthredined larvæ, otherwise known as "false caterpillars."

Soap, syringed in strong suds, will kill some soft-bodied plant-destroyers, and, when used as a paint on the trunks of trees, is an excellent repellant against the parents of various borers.

A mixture of one part of kerosine to three or four of castor-oil, linseed-oil, or whale-oil, thinly brushed all over the trunks and branches of fruit trees affected by apple scale in New Zealand, has been found by Mr. W. M. Maskell to be effective in destroying the pest without injury to the trees.†

A great many substances have at different times been recommended and tried with more or less satisfaction as insecticides. Of these may be mentioned lime, soot, salt, wood-ashes, corrosive sublimate, naphtha, turpentine, alum, carbolic acid, phenyle, cyanide of potassium, blue vitriol (sulphate of copper), hot water, &c. Most of these may be successfully used for specific purposes, either dry, in liquid, or in vapours, but none of them appear to be of any very general use.

* Hubbard's Report on orange insects, dated 1885.

† Scale Insects of New Zealand (Maskell), 1877, p. 33.

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Apparatus.

We have seen that the chief insecticides are applicable in liquids, and thus instruments for atomizing and distributing liquids constitute the most important part of insecticide machinery; what is wanted being a spray nozzle combining ready regulation of the volume to be thrown, greatest atomizing power, with least tendency to clog, facility of cleaning and ready separation of its component parts, cheapness, simplicity, and adjustability to any angle.

The nozzle which best combines these qualities is undoubtedly the eddy or cyclone nozzle, consisting of a small circular chamber with two flat sides, one of them screwed on so as to be readily removed. Its principal feature consists in the inlet through which the liquid is forced being bored tangentially through its wall, so as to cause a rapid whirling or centrifugal motion of the liquid, which issues in a funnel-shaped spray through the central outlet in the adjustable cap. The breadth or height, fineness or coarseness, of the spray, depends on certain details in the proportions of the parts, and specially in the central outlet.

To drive the liquid through the nozzle some kind of force-pump is required, and a great number have at different times been experimented with, some of them being of a most complicated nature. It is perhaps not of any very great consequence which particular form is adopted for use in India; but the aquapult force-pump, which has been arranged to be worked entirely by one man, who also distributes the spray, seems to be about the best suited for general use in a country where economy in labour is generally not so great an object as economy in the cost of apparatus.

Experimental Introduction.

The Indian Museum having now taken up the question of Economic Entomology, it would appear to be the most suitable centre for distributing insecticides, which have not as yet had a fair trial in India.

The following material might be procured for first experiments:—

1. A sufficient number of cyclone nozzles of various sizes and patterns for experiment with the different insecticides on pests affecting growing crops, which vary as to their nature and hence require individual treatment; also force-pumps, as recommended by the United States Entomological Commission.

   The force-pumps and nozzles would be best imported direct from America, under the advice of the United States Entomologist, who might be asked to give his assistance in the matter.

2. A supply of Pyrethrum from the Buhach Producing and Manufacturing Company, Stockton, California, United States.

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3. Supplies of white arsenic, Paris green, London purple, whale-oil soap, kerosene, naphthaline, bysulphide of carbon, and other insecticides, to be obtained locally when possible, otherwise from America.

Precise estimates of the cost of these materials cannot be at present provided, but probably three or four thousand rupees would go far towards obtaining all that are essential for a beginning.

A certain amount of initial expense is necessary to introduce the insecticides, and cover the cost of what is made over to persons capable and willing to conduct experiments and intelligently record the results. But when once the proper methods of applying the insecticides have been determined in the case of each pest, there is no reason why they should not be sold at such a price as to cover all expenses connected with them, and leave a margin of profit, as it may be confidently hoped that a considerable demand will spring up for insecticides when once their value is known.

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